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Title: Review of Neutron Uncertainty Types

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Review of Neutron Uncertainty Types

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The assessment of neutron data requires understanding the uncertainty. The uncertainty of the final quantities of interest, neutron multiplication and mass, is a combination of many other uncertainties because it is a combination of many other variables. The equations for the values of neutron multiplication and mass are quite complex. The relations between the many contributing variables and their uncertainties are complicated leading to complications in combining them. Additionally, some are statistical in nature, while others are systematic. In an effort to better understand and quantify the total uncertainty in neutron multiplication and SNM mass, they have been subdivided into four categories: setup, detector response, nuclear data, and object characterization. This paper discusses the four categories and what types of uncertainties are in each of them. This effort attempts to generalize this process for any neutron detector, but many of our examples show the Next Generation Multiplicity Detector (MC-15).

Setup uncertainties are related to the objects physical location, the detectors physical location, where the object is in relation to the detector, and presence of flooring/walls. These values are the most straightforward to understand, though incorporation of these uncertainties into other sub-equations and eventually into the final neutron multiplication and mass uncertainty is not. The first value is R-D, which is the distance from the floor to the center of the hot spot. This value is fed into empirical fits to guide efficiency determination. The next value is S-D, the distance from the hotspot to the front face of the detector. It too is fed into empirical fits to guide efficiency determination. The uncertainty is this value is a combination of the uncertainty of the physical measurement, the hotspot position, the XYZ offset, and the skewness of the detector relative to the object and the hotspot. The final portion of the setup uncertainty is the presence of flooring/walls. When greater than 1 m away, the walls are known to have a negligible impact on measurements. The wall uncertainty is a combination of the physical measurement, the composition of the walls, and the knowledge of the hot spot. As with the other setup components, this is straightforward to understand and empirically combined to determine efficiency. All setup related uncertainties are statistical- they are based on the precision of physical measurements.

The next category of discussion is detector response. This portion of the uncertainty is detector specific and needs to be determined separately for each detector used. Because the MC-15 is very well characterized, many of the values associated with this system are used in this work. The subcomponents of the detector response category include HV, gas pressure of the He-3 (ie the detection medium), activity of sources used for calibration, detector and object neutron lifetime. The HV is how far the HV is from the assumed value in the HV plateau. While it may drift and become systematic, this is not expected. As such, the variability in the HV is a known and repeatable quantity and thus it is statistical and does not vary from measurement to measurement. It effects the difference between the rates measured for an IPC and the rates measured for calibration/ characterization measurements. Gas pressure is similar to HV the uncertainty is a known and repeatable quantity which effects the efficiency of the MC-15 in detecting neutrons. Detector lifetime is related to both HV and gas pressure, as well as the density of the polyethylene in the MC-15. It is a known quantity with a known uncertainty. System lifetime differs only when the system thermalizes the neutrons sufficiently to make the time longer than the detector lifetime. Uncertainties in system lifetime are related the composition of the object and are quite complex. It is determined based on fitting the R2 parameter, or from Rossi-alpha analysis. It is not

a characteristic directly related to the MC-15. The next subcomponent of the detector response category is the uncertainty in activity of sources used for calibration. The activities, and thus the uncertainties, come from the manufacturers of the specific sources. They are specific to the sources and statistical in nature. Background neutron rates also impact the detector response and cause uncertainty. These vary by location and thus are difficult to quantify. This is generally done by taking a background count rate near the object and assuming the detector response is constant between the object measurements and the background measurements. The uncertainties in the background rates feed into the measurements and thus the uncertainties of the rates of the object.

The next category is nuclear data. Nuclear data refers to the constants used in the equations for mass and multiplication which are specific to the isotopes involved. They include nu bar, moments of the p(nu) distribution, fission cross section (spontaneous and induced), and (alpha,n) cross sections. Most of these uncertainties are given quantities and come from nuclear data libraries. They don't change between measurements, unless the SNM changes. They are generally the most ignored uncertainty because of a historical perspective that they were too small compared to other uncertainties to impact results; however, this perspective is no longer considered to be accurate.

The final category of total uncertainty for neutron multiplication and mass is object characterization. This is also the most complex category. Of note it includes the rates measured and the fits given to them (R1, R2, and R3 values). The fits are complex, especially for R2 and R3 and definitely non-linear. As such, determining the uncertainty for measured rates is a big effort and complex problem. It is not statistical. The next subcomponent is alpha ratio, the ratio of spontaneous fission starter neutrons to alpha-n starter neutrons. This involves knowing the composition of the object and making assumptions about it. The next subcomponent is reflector thickness and type. The uncertainty in the actual reflector thickness effects the understanding of how much material is present, and the efficiency of the detector from the neutrons in the SNM. Related to this is neutron transmission rate which is the apparent source strength of the neutrons- it combines expected efficiency with actual efficiency. Neutron source strength (NSS) is similar. NSS is based on empirical fits from detector characterization. It is statistical in nature. The uncertainties associated with object characterization are quite complex.